May 1973

USDA FOREST SERVICE
RESEARCH NOTE RM- 238

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

An Enclosed Weir for Small Streams in Snow Country

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An enclosed sharp-crested V-notch weir was designed to gage small channels under severe winter conditions at reduced costs of installation and operation. The self-contained structure consists of a multiplate pipe arch with closed ends fitted over an independent cutoff wall. The instrument shelter is mounted directly on the pipe arch over a stilling well assembly placed within the weir basin. The structure provides trouble-free winter operation. Compared to a conventional design, time of construction was reduced 50 percent and total costs by 40 percent.

Oxford: 116.3:51. Keywords: Watershed management, streamflow, measurement systems, weirs.

Sharp-crested V-notch weirs are generally used to measure small but variable flows where sediment and debris loads are not excessive. Under favorable conditions, a 2-foot-high 120° V-notch weir can be used to accurately measure flows from less than 0.1 to about 25 c.f.s. (Reinhart and Pierce 1964). When uncovered, however, such structures are difficult to operate in cold weather, particularly in areas of high snow accumulations. Additional structural features for winter operation greatly increase construction costs.

Successful winter operation of a weir requires that the stilling basin and notch be kept largely free of snow and ice. In deep snow country, the downstream channel must be kept sufficiently open to prevent back-water flooding of the notch, particularly in channels supporting little or no winter flow prior to melt. These requirements are especially difficult to meet in windswept areas where deep snowdrifts accumulate in the stream channels. In many areas above 7,000 feet on Wyoming's high plains, for example, drifts of 45 percent density up to 25 feet deep are common. Such drifts make flat-decked covers over the weirs impractical, and annual excavation of escape channels impossible.

Under the best of conditions, permanent and accurate control sections are expensive; structural modifications for protection against heavy snow loading make them even more so. This Note presents a design for a relatively inexpensive sharp-crested V-notch weir which we have operated successfully in winter on a high-elevation research site in southcentral Wyoming.

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Derivation of the Design

During the first winter after construction, the control section of an uncovered weir on the research area was buried under 17 feet of snow, necessitating repeated excavation. At the time of peak accumulation, the structure was sub-

Figure 1.—A sharp-crested weir covered by a multiplate arch. The ends of the arch were later enclosed.

jected to loading in excess of 500 pounds per square foot. The following summer, a corrugated multiplate arch (40-foot length, 28-foot span, 8-foot rise) was built over the entire weir (fig. 1). Although the arch was designed to withstand the snow load experienced the first year, its rise reduced the maximum expected snow depth at its crest to about 6 feet.

This quonset hutlike structure has allowed the streamgage trouble-free winter operation (fig. 2). It led to consideration of a unit weir — a control section installed within a multiplate pipe arch, wherein the pipe would act at once as stilling basin, apron, and cover. The approach promised important cost savings, and appeared to be particularly suitable for gaging small channels in deep snow country.

The Enclosed Weir

The enclosed weir is of a scale suitable for accurate measurement of heads up to 1.5 feet, meeting the minimum hydraulic requirements in pond depth and width (about 2.5H) specified by King (1954). Detailed information on construction is available upon request.[2] The specific dimensions may be altered to suit a particular weir site. The principal features of the unit weir are:

[2] *Address requests to Forest, Range, and Watershed Laboratory, Rocky Mountain Forest and Range Experiment Station, University of Wyoming, Box 3313, Laramie, 82071. Detailed construction plans are for the North Fork Loco Creek weir, Carbon County, Wyoming, approved April 22, 1971.*

Figure 2.—The arch-covered weir under moderate winter conditions.

1. **Pipe arch.**—The basic structure is a multi-plate pipe arch, of 12-gage galvanized steel (30-foot length, 16-foot 7-inch span, 10-foot 1-inch rise). Pipe arches of many other nominal dimensions are readily available from commercial suppliers. The span and rise dimensions can be selected to meet the hydraulic requirements of any size weir. The pipe arch can be as long as desired; the 30 feet selected here was a normally manufactured size which allowed a stilling basin of 20 feet and a discharge apron of 10 feet. The bottom and sides of the pipe arch are slotted to fit over the cutoff wall. Figures 3 and 4 present plan and elevation views of the structure.

2. **Cutoff Wall.**—The control section, a 2-foot 120° V-notch, is mounted in a cutoff wall made of 12-gage steel sheeting, interlocking type 'B'. The portion of the wall within the pipe arch is braced by angle-iron wales, bolted to the individual plates. A 12-inch sliding gate valve, to allow periodic flushing of deposited sediment through the structure, completes the cutoff wall (fig. 5). The gate's relatively high placement was necessitated by low channel gradients where the structure has been used, and by our requirement that the notch be placed at or below the elevation of the original channel to reduce leakage.

The dimensions of the wall should be dictated by soil and geologic conditions of the weir site to minimize leakage. Because consolidated bedrock could not be reached at reasonable depth on the sites where the structure has been installed, the cutoff wall extended only 4 feet below the bottom of the pipe arch. Leakage was minimized by carefully compacting a soil-bentonite backfill around the wall. Under other conditions, and because it is independent of the pipe arch, the cutoff wall could be constructed of concrete or other suitable materials keyed into bedrock.

We recommend that the cutoff wall be placed within the pipe arch, but independent of it. Although the wall could be placed at the upstream end of the pipe arch to act as both cutoff and head wall, this would require that the control section be contained wholly within the pipe. If so placed, all joints and connections between walls and pipe arch, and the pipe arch itself upstream of the control section, would have to be watertight—a state both difficult and expensive to attain. This approach also is undesirable because the control section would be an integral part of the pipe arch; any settling or displacement of the pipe would directly affect the control section as well.

3. **Instrument Shelter.**—A stream-gage shelter, based on a standard U.S. Geological Survey plan, is mounted directly on the pipe arch. One end of the 48-inch corrugated metal pipe is cut to match the arch radius, and welded to a 'saddle' formed of an additional arch plate of the same radius. The saddle is then bolted to the arch over a hole cut to match the vertical projection of the shelter. The shelter thus becomes an integral part of the structure, providing access to the interior of the arch as well as housing all needed instruments.

4. **Stilling Well Assembly.**—An 18-inch corrugated metal pipe forms the stilling well, set within a shorter 24-inch pipe which acts as a heat sleeve. The two are joined by the inlet and drain pipes and by a metal plate welded to their bases to create a watertight, dead air space around the stilling well. If desired, a small heater may be suspended within the space and the heat sleeve covered to help prevent the stilling-well water from freezing.

The assembly is placed directly beneath the instrument shelter within the stilling basin, strapped to the pipe arch.

5. **End Covers.**—The upstream end of the structure is largely closed by the head wall. It is similar to the cutoff wall, formed of interlocking type 'B' steel sheeting, stiffened by angle-iron wales. Because its chief functions are to direct surface water into the weir and prevent erosion of backfill, the head wall is only slightly wider than the pipe arch span.

The upper portion of the upstream end, and all of the downstream end, are enclosed with 20-gage corrugated sheeting bolted to horizontal angle-iron supports secured directly to the pipe arch. Small openings are left for water entry and escape. Where necessary to exclude blowing snow, butyl rubber flaps can be fastened over the openings. Once the snowpack has covered the structure, the flap can be opened from the inside, well before the onset of snowmelt.

6. **Escape Pipe.**—In a drifting snow environment, streams with low gradients, particularly intermittent channels, may require piping to maintain an adequate escape channel for peak snowmelt flows. Corrugated aluminum piping, for ease of installation, is laid in the channel downstream, with its upper end placed inside the structure on the apron floor. The diameter of the pipe should be dictated by the expected volumes of flow, and its length by the gradient of the downstream channel.

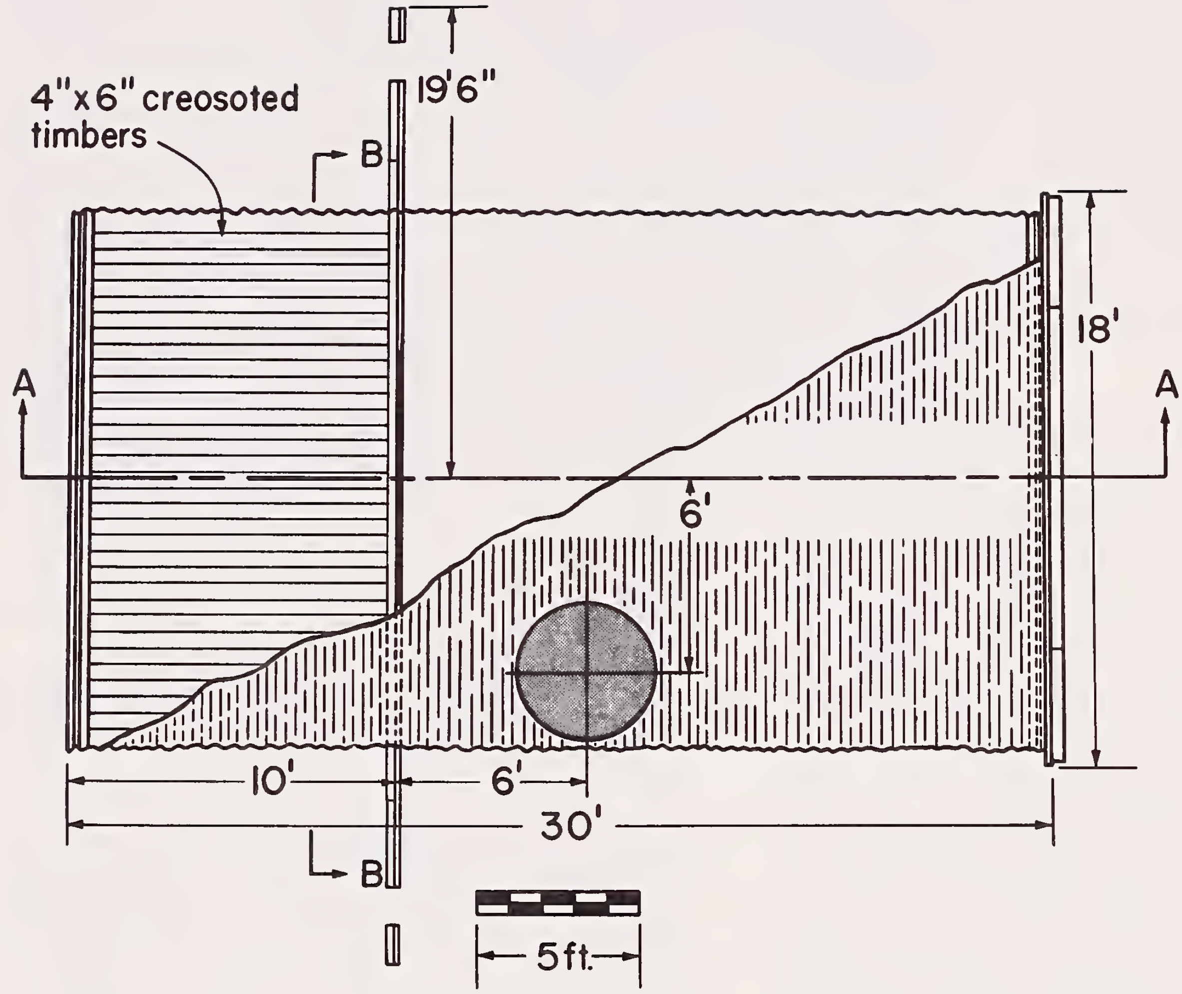

Figure 3.—
Plan view of
the enclosed
weir.

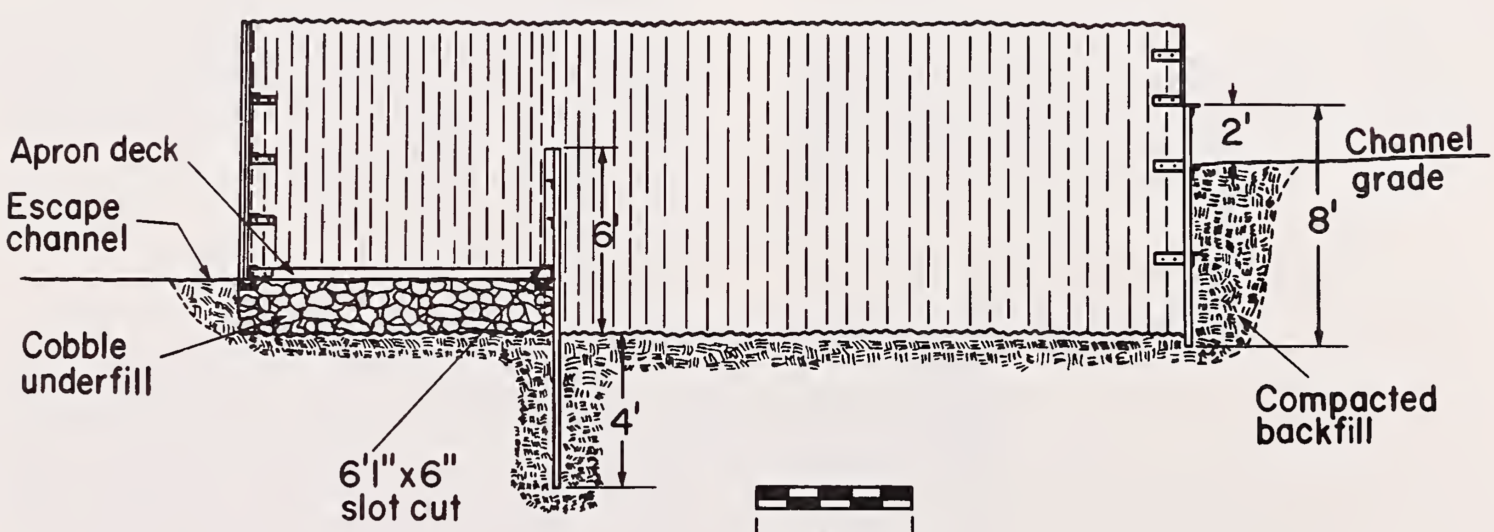

Figure 4.—Section A-A: elevation view at centerline of the enclosed weir.

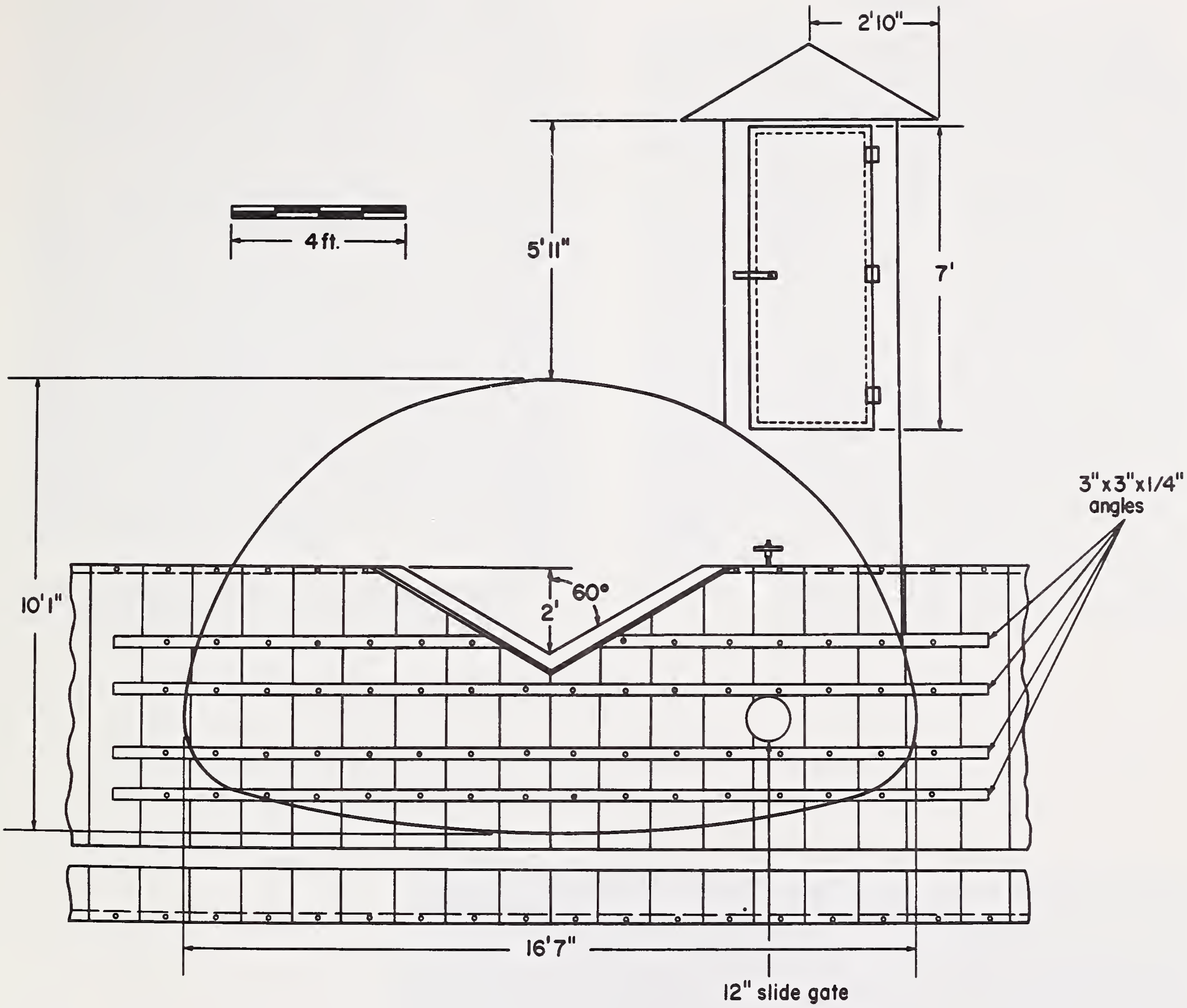

Figure 5.—Section B-B: view at cutoff wall of the enclosed weir.

Installation

We have installed two enclosed weirs by different construction techniques. One weir was completely assembled and fitted in a machine shop, partially disassembled, and transported to the weir site as five modular units: cutoff wall, head wall, apron portion of the pipe arch including its end cover, instrument shelter, and stilling well assembly. Actual installation of the weir largely involved reassembly of the modular units. This procedure requires heavy machinery to lift the several units into place.

The second weir was assembled and fitted at the weir site. The instrument shelter and stilling well assembly were transported to the weir site as modular units. All angle-iron wales were cut to length and drilled, and all support brackets and braces were prefabricated. The entire weir, aside from the two modular units, was built in place. Equipment necessary to construct the enclosed weir by either method of installation include a motor grader, backhoe, bulldozer or front-end loader, dump truck, air compressor, field welder, and torch.

Construction begins with excavation of the cutoff wall trench and pipe-arch bed. The cutoff wall is either lifted into the trench as a complete unit or constructed in place, braced into position, and backfilled with a bentonite-soil mixture. Next the pipe-arch bed is shaped into a rough approximation of the structure's lower curve. In the modular form of construction, the entire apron section of the pipe arch is then lifted into place against the cutoff wall. The lower half of the pond section is bolted together and laid into place as a unit, and the remaining plates are installed to close the arch. Alternatively, the pipe arch can be erected in place, by conventional multiplate construction techniques. With either method of construction, the preassembled head wall, instrument shelter, and stilling well assembly can be lifted into place and secured. Placement of the end covers and butyl rubber flaps close the structure against snow. Only the final construction details remain to complete the weir (figs. 6 and 7).

The enclosed weir can be installed quickly by either technique. Modular assembly of the

Figure 6.—A nearly completed enclosed weir showing the instrument-shelter mounting and cutoff wall placement.

weir, including transportation of components to the weir site, required about 20 man-days by a crew of one to three men. Time spent in assembly and shop fitting of the structure was included in the purchase contract for materials. Inclusion of this labor would make the total number of man-days spent in construction much higher.

The field-assembled structure required approximately 60 man-days by a crew of one to four men. For comparison, construction of a conventional weir of about the same overall size required approximately 155 man-days. The conventional weir consisted of a concrete cutoff wall, treated-timber apron, headwall, stilling basin (with no floor), a detached stilling well and instrument shelter, and a multiplate-arch cover. The economy in construction time with the enclosed weir not only reduces cost, but could be important in areas with a short construction season between late spring snowmelt and early fall accumulation.

Cost of Construction

The total cost, exclusive of instruments, for installation (modular assembly) of the first enclosed weir in early 1970 was $16,850. This amount included excavation of 250 feet of escape channel, construction of a 500-foot access road, and final dressing of the site.

The costs of field assembly of the enclosed weir provide a more direct comparison with the costs of conventional weir construction. The weir was constructed in 1971 by the Medicine Bow National Forest construction crew, for a total cost of $11,530. This amount does not include money spent for an access road or excavation of the escape channel — the two most variable factors in total costs. Excluding the same variables, costs for a conventional weir (including an estimated figure for an arch cover) were approximately $14,875 in 1968. Applying a 10 percent annual rise in construction costs, the adjusted 1971 price would have been roughly $19,800.

Figure 7.—Interior view of the enclosed weir looking downstream.

Applications

The enclosed weir was designed to gage small channels under severe winter conditions where sediment and debris loads are not excessive. The structures have protected the control section and the instruments for 2 years, and have allowed ready winter access to the streamgage for periodic servicing (fig. 8). Once the arch becomes snow covered, the stilling basin and notch stay ice-free. The escape pipe eliminates backwater effects, and minimizes excavation of the downstream channel. In addition, the pipe arch provides a convenient means for installing radiant heaters to prevent ice formation, where this might be necessary, and for housing sediment samplers and other instruments used in associated data collection.

The enclosed weir offers important economies in both time and cost of construction. Time of construction can be reduced by 50 percent or more, and the total costs may be as much as 40 percent less. In locations where snow loading is not a problem, the enclosed weir, with escape pipe and end covers deleted, would offer even stronger cost reductions. Where weirs can be used, the design may have ready application to low-elevation grassland situations as well.

With excavation of snow reduced to a minimum, the design provides savings in operational costs which are hard to quantify but are substantial. The enclosed weir facilitates routine servicing of the stream gage, and provides a reliable, continuous record of streamflow.

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Figure 8.—The enclosed weir under typical winter conditions.